

STATE OF ALASKA

William A. Egan, Governor



Annual Progress Report for

SILVER SALMON STUDIES
IN THE RESURRECTION BAY AREA

by

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RESEARCH PROJECT SEGMENT

State: Alaska

Project No.: F-9-4 *Name:* Sport Fish Investigations of Alaska.

Study No.: G-11 *Study Title:* Sport Fish Studies. .

Job No.: G-11-A *Job Title:* Silver Salmon Studies in the
Resurrection Bay Area.

Period Covered: July 1, 1971 to June 30, 1972.

ABSTRACT

This report is a continuation of studies initiated in 1960 on silver salmon, Oncorhynchus kisutch, in the Resurrection Bay area.

Bear Lake and tributaries were treated with 8,030 gallons of 5% emulsified rotenone (Pro-Noxfish) on July 21 and 22, 1971. The rehabilitation was believed successful in obtaining a complete eradication of all fish. Species composition samples collected randomly revealed that threespine stickleback, Gasterosteus aculeatus, comprised 98.8% of the population.

The Bear Creek weir operated from May 25 to July 20. The silver salmon smolt out-migration totaled 1,873 silver salmon smolts. Age composition of the migration was 10.5% age 1.0, 83.3% age 2.0, and 6.2% age 3.0 smolts. Mean fork lengths for the age 1.0, 2.0, and 3.0 smolts were 103.0, 122.0, and 151.6 mm, respectively.

The Seward small boat harbor creel census was conducted from July 12 through September 10. An estimated 20,595 silver salmon were harvested in Resurrection Bay by 26,485 man-days of sport fishing effort. Marked, hatchery-reared silver salmon smolts (1968 brood, Bear Lake stock) planted in local tributaries in 1970 returned as adults in 1971, and comprised 22.0% of the season's sport harvest.

RECOMMENDATIONS

1. Retain the present objectives of the study.
2. Adhere to the Alaska Board of Fish and Game's Bear Lake Management Policy of February 22, 1971.
3. Investigate potential sites in the Resurrection Bay drainage to excavate natural rearing ponds for juvenile silver salmon.

OBJECTIVES

1. To collect and analyze biological data concerning the distribution, abundance, and timing of out-migrant and adult silver salmon in the Resurrection Bay area.
2. To determine the age and size compositions of out-migrant and adult silver salmon populations in selected tributaries.
3. To determine the sport harvest of silver salmon in Resurrection Bay and natural mortality in salt water.
4. To evaluate the freshwater environmental limitations on juvenile silver salmon production in this area.
5. To determine the methods and means of increasing or extending the freshwater spawning and rearing areas of the watershed, and mitigating freshwater mortality.
6. To provide recommendations for the management of silver salmon in these waters and direct the course of future studies.

TECHNIQUES USED

The timing and abundance of silver salmon smolts and fry emigrating from Bear Lake were determined by enumerating these downstream migrants through the Bear Creek weir downstream migrant trap. Weir location and the downstream trapping facilities were described by Logan (1969). The timing and abundance of adult red salmon migrating to Bear Lake were measured by enumerating these fish through the weir's upstream migrant trap. Upstream trapping facilities were described by McHenry (1971). Bear Creek water temperatures and stream flows were recorded daily at the weir.

The age structures of Bear Lake silver and red salmon smolt out-migrations were determined by examining representative scale impressions on 0.02-inch thick cellulose acetate with a microprojector. Age composition of the Bear Lake adult red salmon escapement was determined by scale sample analysis. Size compositions of salmon smolt populations were determined by random length and weight samples collected weekly at the weir. These fish were anesthetized in a 1:20,000 solution of MS-222 to facilitate sampling and minimize handling mortality. Size composition of the adult red salmon escapement was determined by length and weight measurements per sex.

The Resurrection Bay silver salmon sport harvest and effort were measured by a stratified, random creel census conducted at the Seward small boat harbor. The sampling design and interview method were nearly identical to that described by Logan (1966). Fishing mortality was determined by examining as many silver salmon as feasible during creel census interviews to ascertain the harvest of marked (fin clipped) fish resulting from the 1970 smolt plants in local waters.

An index to silver salmon escapement abundance was measured by conducting weekly foot surveys on seven index streams. All carcasses were examined for clipped fins, sexed, and mutilated to preclude recounting on subsequent surveys.

The Bear Lake system was rehabilitated with emulsified rotenone to increase the freshwater rearing area and to mitigate freshwater mortality of juvenile silver salmon in that watershed. The techniques used in the lake treatment are discussed under "Findings" in the Bear Lake Rehabilitation section.

FINDINGS

The findings presented are the result of the 1971-72 research segment of this project. For a description of the Resurrection Bay drainage and past information collected on the project, see Dunn (1961), Logan (1962-1969), and McHenry (1970;1971).

Bear Lake Project

Bear Lake was selected for the study and enhancement of salmon populations because it is the largest body of fresh water in the Resurrection Bay drainage, is an important salmon producer, and is accessible by road. The 445-acre lake offers the most stable rearing potential for silver salmon, Oncorhynchus kisutch, smolt production in the drainage since it is not subject to the widely fluctuating stream flows and water temperatures characteristic of the drainage's tributaries.

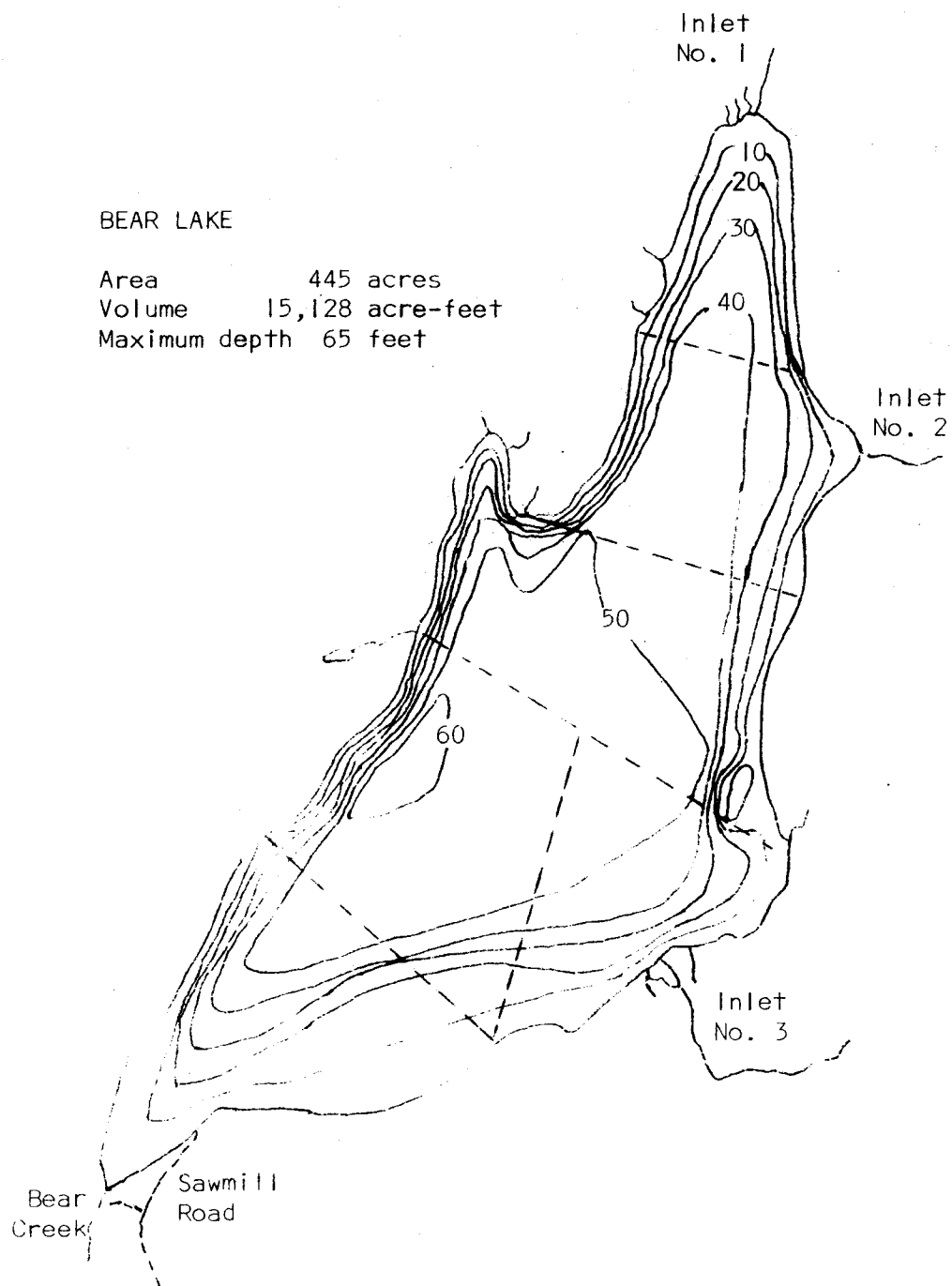


FIGURE 1. MAP OF BEAR LAKE. DASHED LINES INDICATE QUADRANTS DELINEATED BY COLOR-CODED BUOYS FOR ROTENONE APPLICATION PER VOLUME.

Bear Lake Rehabilitation

Bear Lake and tributaries were rehabilitated on July 21 and 22 with 8,030 gallons of 5% emulsified rotenone (Pro-Noxfish). This lake rehabilitation project was funded jointly by Anadromous Fish Act (PL 89-304) monies and State matching funds.

Figure 1 presents a map (Logan, 1964) of the Bear Lake basin and tributaries. Three main inlets and one headwater pond have fish migration barriers (canyon falls), temporary runoff streams, and Bear Creek downstream to the weir were repeatedly treated by backpack sprayers, drip stations, and shoreline spraying. A 5-foot high dam was constructed at the outlet to contain the treated lake water to prevent fish kills in the main tributary, Salmon Creek. Diluted toxicant was applied to the lake surface by four skiff-mounted centrifugal pumping units with adjustable valves to regulate the water and rotenone dispersion. The lake surface was delineated into six quadrants (Figure 1) by color-coded buoys, and the amount of toxicant used was predetermined for the lake volume contained in each quadrant. Rotenone was also pumped via weighted hoses below the lake's thermocline (15-21 feet) into the 50+ foot depths to ensure toxicant penetration and mixing in the dense, cold water strata. Population distribution tests in 1970 showed that threespine stickleback, Gasterosteus aculeatus, inhabited all depths to 60 feet in Bear Lake (Engel, 1971).

An attempt was made to draw down Bear Lake's normal volume (15,128 acre-feet) so as to require less toxicant for rehabilitation. The 1 1/2-foot high outlet weir was removed in early June, which normally would have allowed sufficient time (six weeks) to accomplish this. However, an extended runoff of the abnormally heavy snow pack that accumulated in the watershed during the 1970-71 winter maintained the lake at its normal volume. The toxicant concentration was computed at 1.60 ppm, or 0.08 ppm rotenone/sulfoxide, for this lake volume.

Scuba diving to inspect live fish cages suspended from surface to bottom (40 and 60 feet) in two areas of the lake disclosed that all test fish died within one week after treatment. Periodic observations along the shore and inlets indicated that the rehabilitation was successful in obtaining a complete eradication of all fish inhabiting Bear Lake. Further confirming this is that Bear Lake surface outflows (Bear Creek) were lethal to caged juvenile silver salmon for approximately six months after rehabilitation. After fall overturn occurred in late October (the lake was homiothermous on October 16), Bear Lake gradually detoxified from the surface downward. In February through April, 1972, test fish survived for several weeks from the surface down to 50 feet, but died rapidly at the 55- and 60-foot levels. Dissolved oxygen determinations made on April 7 indicated 11 ppm oxygen concentration down to 40 feet and 8.5, 3.5, and 0.5 ppm at the 50-, 55-, and 60-foot depths, respectively. That test fish died at 55 feet despite sufficient oxygen present to sustain fish life, strongly suggests that residual rotenone toxicity caused the fish mortality at this depth. Other researchers

(Engel, 1971; Redick, personal communication) studying detoxification durations in two rehabilitated southcentral Alaskan lakes found, similarly, that rotenone breakdown apparently decreased with increased depth, according to vertical toxicity tests using caged fish. Bear Lake completely detoxified soon after spring overturn occurred in early June, 1972.

It was roughly estimated that Bear Lake would completely detoxify in about 90 days at 1.6 ppm concentration as compared to 52 days required at 1.0 ppm after the 1963 rehabilitation. A total of 450,000 silver salmon fingerling were to be planted in the lake prior to freezeup. However, due to the aforementioned extended snow melt, Bear Lake waters did not heat sufficiently to cause a similar rate of rotenone deterioration to that observed in 1963. Figure 2 illustrates the differences in Bear Lake's surface, mid-depth (30 feet), and bottom (60 feet) water temperatures for 1963 and 1971. The Bear Lake water column in 1971 averaged 3.9°C (7.0°F) colder than in 1963. Post (1958), according to S. B. Penick & Company (1963), concluded from his experiments in Wyoming that "the most apparent chemical or physical property which affects the breakdown of rotenone is temperature," and "total dissolved solids, pH, alkalinity, and dissolved oxygen apparently do not change the rate of breakdown to any great extent."

Fish population samples collected randomly on and around Bear Lake two days following treatment revealed that the lake could no longer rear substantial numbers of juvenile salmon due to extreme competition for survival from threespine stickleback. Table 1 illustrates the dominance that stickleback had over other fish species inhabiting Bear Lake. Excluding the fish collected in the three inlets (99.6% Dolly Varden, Salvelinus malma), stickleback comprised 98.8% of the lake's fish population. Figure 3 presents a length frequency histogram of the stickleback population sample. These fish ranged from 15 - 92 mm, with a mean of 35.4 mm. Population sampling throughout June, 1970, indicated that a unimodal distribution with a mode of about 48 mm existed for the Bear Lake stickleback population during that period (Engel, 1971). Smaller fish, either young-of-the-year or a late hatched brood from 1969, entered the samples in early July, 1970, in increasing abundance. Apparently, these fish predominated in the 1971 population, with relatively few large individuals appearing in the post-rehabilitation sample. Of the 12 juvenile silver and red salmon (O. nerka) measured, only four silver and one red salmon were of sufficient size to "smolt" during the 1971 season. However, since population sampling was conducted at least 1/2-mile above the outlet, the normal peak of smolt emigration was well past, these fish probably would have remained in the lake until the following year. cursory observations made near the outlet revealed no higher concentration of juvenile salmon there than that observed in the areas sampled.

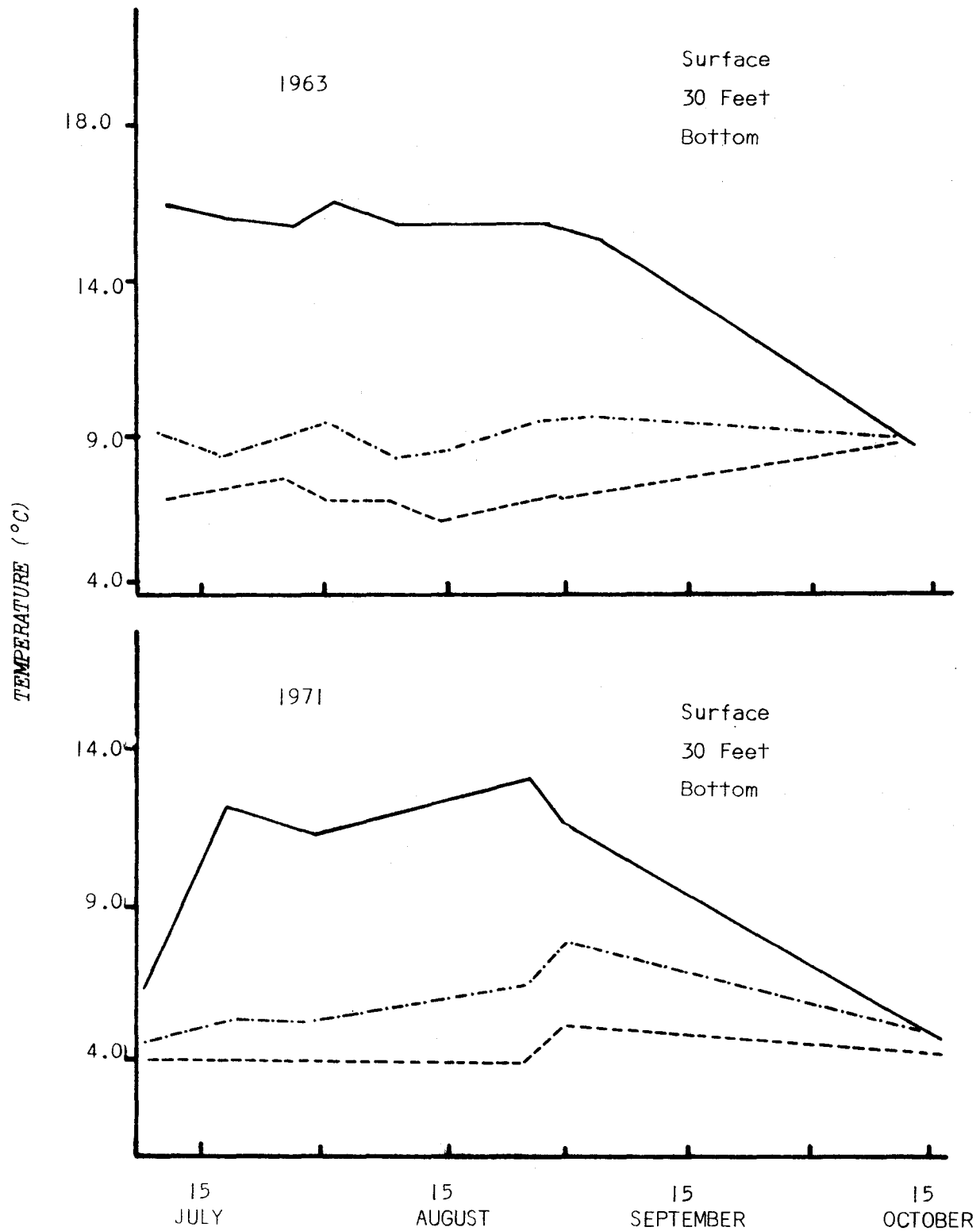


FIGURE 2 BEAR LAKE TEMPERATURES IN 1963 AND 1971.

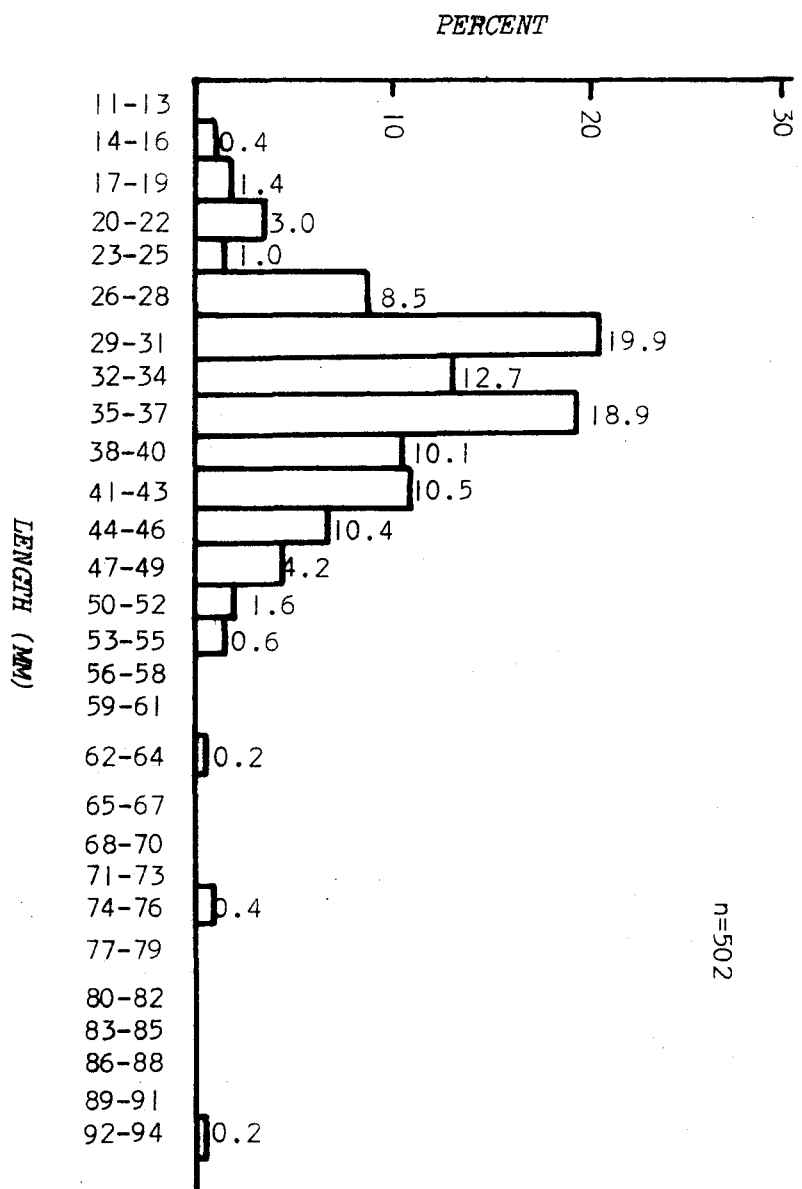


FIGURE 3 LENGTH FREQUENCY HISTOGRAM OF BEAR LAKE STICKLEBACK,
JULY 24, 1971.

TABLE I Fish Population Samples Collected Randomly on and around Bear Lake, July 24, 1971, Two Days Following Rehabilitation.

Sampling Area	Species*	No. Fish Collected	Percent	No. Fish Measured	Mean Length (mm)
Three Beaches With Inlets	SB	6,256	98.6	502	35.4
	DV	76	1.2	58	59.6
	SS	13	0.2	2	99.5
	RS	2	--	1	77.0
Subtotal		6,347	100.0		
One Beach Without Inlet	SB	1,219	99.4	-	--
	DV	4	0.3	4	64.0
	SS	2	0.2	2	85.0
	RS	1	0.1	1	46.0
Subtotal		1,226	100.0		
Surface Tows, Open Water	SB	1,247	99.6	-	--
	RS	5	0.4	5	34.8**
Subtotal		1,252	100.0		
Three Inlets	DV	239	99.6	239	46.7
	SS	1	0.4	1	143.0
Subtotal		240	100.0		
Total	SB	8,722	96.2	502	35.4
	DV	319	3.5	301	38.6
	SS	16	0.2	5	102.4
	RS	8	0.1	7	42.4
		9,065	100.0		

*SB - Threespine stickleback

SS - Silver salmon (juvenile)

DV - Dolly Varden

RS - Red salmon (juvenile)

**Four fish were 0+ fry (27 - 30 mm) and one fingerling, 60 mm.

Bear Lake Downstream Migration

Silver Salmon:

The Bear Creek weir was operated continuously from May 25 through July 20, the last day of weir operation. No silver salmon smolts entered the downstream trap until June 8, indicating that smolt migration had not begun before the downstream migrant screens and trap were operational. Bear Creek was dewatered on July 21 as a result of damming Bear Lake prior to lake rehabilitation.

The total out-migration enumerated through the trap was 1,873 smolts and 4 fry. Trap mortality claimed seven smolts (0.4% of the out-migration), allowing 1,866 smolts and 4 fry to be released downstream. All smolts and fry were unmarked (wild) fish. Marked fingerling plants in Bear Lake were discontinued after 1967 because its smolt production had declined. The last marked smolts surviving the 1967 fingerling releases were age 3.0, and emigrated in 1970. The timing and abundance of the Bear Lake smolt and fry migrations are presented in Table 2. The smolt out-migration began on June 8, with the highest daily count (278 fish) occurring on July 20. The stream temperature when smolt out-migration began was 2.2°C (36°F) and 11.2°C (52°F) on July 20. Stream flows fluctuated from 51 - 105 cfs during this period; however, the peak flows occurred as a result of the attempt to draw down Bear Lake's volume prior to lake rehabilitation.

TABLE 2 Silver Salmon Smolts and Fry Enumerated through Bear Creek Weir by Weekly Periods, 1971.

Weekly Periods	Wild Origin	
	1967-1969 Broods (Unclipped)	1970 Brood (Fry)
6/ 3-6/ 9	18	-
6/10-6/16	55	-
6/17-6/23	75	1
6/24-6/30	250	3
7/ 1-7/ 7	439	-
7/ 8-7/14	544	-
7/15-7/21	492	-
Total	1,873	4
No. Dead	7	-
No. Released*	1,866	4

*An unknown number of released smolts died in lower Bear Creek when rotenone-treated water percolated through the weir.

Due to the necessity of rehabilitating upper Bear Creek to prevent undesirable fish species from subsequently reinfesting Bear Lake, additional smolts were killed. An unknown number of silver salmon smolts died above the weir as a result of rotenone treatment. The number of silver salmon smolts that had not emigrated from Bear Lake before rehabilitation occurred is also unknown, but believed to be few. Therefore, the minimum Bear Lake silver salmon smolt production in 1971 was estimated at 1,873 fish. Despite efforts to physically move all stranded fish from dewatered lower Bear Creek into Salmon Creek, an unknown number of released smolts died from the

upstream rotenone-treated waters percolating through the weir and low dissolved oxygen in the overcrowded pools. To offset the anticipated poor silver salmon smolt production from Bear Lake in 1971, a total of 51,100 adipose fin (Ad) marked age 1.0 smolts (1969 brood, Bear Lake stock) were released in Bear Creek below the weir in May.

A total of 228 scale samples were randomly collected from silver salmon smolts between June 11 and July 26 (upstream mortality). Table 3 shows the age composition as well as mean fork length and range for three age groups of smolts sampled weekly throughout migration. The extrapolated number and age composition of the 1,866 smolts released past the weir were estimated as follows: 196 age 1.0, 1,555 age 2.0, and 115 age 3.0 fish. Fork lengths of 49 smolts measured during the peak of migration, July 8 to 14, ranged from 97 - 154 mm, with a mean of 120.9 mm.

The 197 age 1.0 smolts resulted from the 1969 Bear Lake escapement of 523 males and 245 females. The 1,560 age 2.0 smolts originated from the 1968 escapement of 2,280 males and 1,175 females. The 116 age 3.0 smolts were produced by the 1967 escapement of 2,661 males and 1,452 females. Adults spawning in these brood years were of mixed Bear Lake and Swanson River stocks.

Other Species:

A total of 400 Dolly Varden were captured from June 6 to July 15. The highest daily count occurred on June 26 when 80 fish (20.0% of the migration) were enumerated. The majority (69.3%) of these char had migrated past the weir by June 30 on their seaward migration. Additional char were killed in upper Bear Creek as a result of stream rehabilitation. The minimum downstream migration, therefore, was 400 char.

The total red salmon smolt out-migration enumerated from the trap was 3,295 fish. Trap mortalities claimed 36 smolts, or 1.1% of the migration. The first smolt was captured on May 30, and the highest daily count occurred on June 29 when 338 smolts (10.3% of the migration) were enumerated. The stream temperature at the beginning of downstream migration was 1.1°C (34°F) and stream flow, 44 cfs. Additional red salmon smolts were killed in upper Bear Creek. The minimum total red salmon smolt out-migration, therefore, was an estimated 3,295 fish. This migration was comprised of 58.6% age 1.0, 40.7% age 2.0, and 0.7% age 3.0 smolts as determined by analyzing 263 scales collected weekly throughout migration. Mean fork lengths of the age 1.0, 2.0, and 3.0 smolts were 70.0, 79.9, and 156.0 mm, respectively. Fork lengths of 49 smolts measured during the peak of migration, June 23 to 30, ranged from 59 - 95 mm with a mean of 73.1 mm.

A total of 1,129 threespine stickleback were captured during the period of downstream migrant trap operation. The highest daily count (238 fish) occurred on July 20, indicating that a substantial portion of the downstream

TABLE 3 Mean Fork Lengths and Ranges (mm) of Three Age Classes of Silver Salmon Smolts Sampled at Bear Creek Weir by Weekly Periods, 1971.

Weekly Periods	Age 3.0 (1967 Brood)			Age 2.0 (1968 Brood)			Age 1.0 (1969 Brood)		
	No.	Length (mm)		No.	Length (mm)		No.	Length (mm)	
		Range	Mean		Range	Mean		Range	Mean
6/10 - 6/16									
6/17 - 6/23				1	110	---	4	68 - 104	95.8
6/24 - 6/30	2	161 - 174	167.5	33	105 - 140	111.3	6	99 - 115	104.7
7/ 1 - 7/ 7	2	152 - 160	156.0	41	102 - 137	118.7	3	86 - 114	105.0
7/ 8 - 7/14	3	132 - 150	143.0	37	101 - 154	124.4	6	97 - 112	102.3
7/15 - 7/21	3	137 - 145	140.7	36	104 - 138	122.1	1	115	---
7/22 - 7/28*	<u>4</u>	147 - 172	156.0	<u>42</u>	109 - 157	131.7	<u>4</u>	95 - 121	105.3
Total	14	132 - 174	151.6	190	101 - 157	122.0	24	68 - 121	103.0
Percent	6.2			83.3			10.5		

*Smolts sampled during this period died above the weir as a result of stream rehabilitation.

migration probably would have continued if Bear Lake had not been rehabilitated. The percentage of the 1968, 1969, and 1970 stickleback emigrations occurring after July averaged 60.9%. Many additional stickleback were killed above the weir.

Resurrection Bay Silver Salmon Harvest and Effort

A creel census to determine the Resurrection Bay silver salmon sport harvest and effort was initiated at the Seward small boat harbor on July 12 and terminated on September 10. Silver salmon first entered the sport fishery on July 8, according to local charter boat operators. The total season's harvest was estimated at 20,595 silver salmon. This estimate was extrapolated from interviews with 7,319 completed anglers harvesting 5,638 silver salmon during the stratified, random creel census. The peak of the harvest occurred on August 14, the first day of the Seward silver salmon derby, when an estimated 2,145 fish (10.4% of the season's harvest) were taken. The total and derby harvests are summarized for 1967 through 1971 in Table 4. A substantial portion of the 1971 harvest (46.1%) occurred during the derby, extending from August 14 to 22.

TABLE 4 Derby and Total Sport Harvests of Silver Salmon in Resurrection Bay, 1967-1971.

<u>Year</u>	<u>Tot. Sport Harvest</u>	<u>Derby Harvest</u>	<u>% Derby Harvest</u>
1967	17,380	6,289	36.2
1968	22,560	8,187	36.2
1969	15,040	5,150	34.2
1970	14,865	5,440	36.6
1971	20,595	9,488	46.1

The average number and percentage of sport fishing boats returning to the Seward small boat harbor were determined for each of the three 3.5-hour sampling periods extending from 11:30 AM to 10:00 PM. These are presented in Table 5. The period from 8:00 to 11:00 AM was not sampled in 1971 because only 11.6 and 14.3% of weekend and weekday sport craft, respectively, returned during this period in 1964 through 1966. The mean number of craft returning during this period based on these percentages was added to those for the three periods sampled to determine the total daily boats. The greatest number of boats returned between 3:00 and 6:30 PM. The average number of anglers per boat was as follows: weekdays, 3.39; weekends, 3.35,

and salmon derby, 3.02. Sport fishing effort (man-days) was calculated by multiplying the total number of boats times the average number of anglers per boat. The average number of hours each angler fished per day was as follows: weekdays, 6.49; weekends, 6.47; and salmon derby, 7.41.

TABLE 5 The Mean Number and Percentage of Sport Fishing Boats Returning to the Seward Small Boat Harbor during Each Sampling Period, 1971.

Sampling Periods (Hrs.)	Weekends		Weekdays	
	Mean No. Boats	%	Mean No. Boats	%
8:00 AM-11:30 AM*	13.1	11.6	4.2	14.3
11:30 AM- 3:00 PM	28.9	25.5	5.7	19.2
3:00 PM- 6:30 PM	46.3	41.0	12.3	41.5
6:30 PM-10:00 PM	24.7	21.9	7.4	25.0
Total	113.0	100.0	29.6	100.0

*Percentage for this period determined by three-year mean, 1964-1966.

The total sport fishing effort exerted for silver salmon was an estimated 26,485 man-days. During the creel census period 27.6% of this effort was sampled. Fishing effort and mean catch per hour since 1967 are summarized in Table 6. The fishing effort on weekends and weekdays, excluding the derby, was 6,475 and 7,022 man-days respectively. Military personnel and dependents, angling from boats provided by the Army and Air Force recreation camps at Seward, contributed 20.3% (5,378 man-days) of the total effort. The seasonal mean catch per hour was 0.11 silver salmon. Civilian anglers fishing during weekdays realized the highest catch per hour (0.17 fish), whereas the lowest catch rate (0.06 fish) occurred during the derby when effort was greatest.

TABLE 6 Derby and Total Sport Effort (Man-Days) Exerted for Silver Salmon, and Mean Catch per Hour in Resurrection Bay, 1967-1971.

Year	Census Period	Total Effort	Derby Effort	% Derby Effort	Catch/ Hr.
1967	7/12-9/12	20,100	8,505	42.3	0.15
1968	7/ 6-9/10	25,350	11,590	45.7	0.15
1969	7/ 9-9/ 9	24,655	11,262	45.7	0.12
1970	7/ 3-9/ 8	27,125	14,955	55.1	0.08
1971	7/12-9/10	26,485	12,988	49.0	0.11

King, O. tshawytscha, and pink salmon, O. gorbuscha, were incidentally taken with silver salmon during the season. Small "feeder" king salmon were unusually abundant in Resurrection Bay from early July through August. Since king salmon are relatively scarce in the Resurrection Bay drainage, these immature fish were probably of non-indigenous stocks, temporarily rearing in Resurrection Bay. An estimated 2,386 king salmon were harvested during the census period at an average catch rate of 0.27 fish per boat. Mean catch rates for king salmon from 1968 to 1970 range from 0.06 to 0.07 king salmon per boat. These fish were most abundant in the 1971 fishery from the first week of creel census through July 28 when anglers averaged 0.61 king salmon per boat.

Pink salmon abundance was at its typical odd-year low in Resurrection Bay, as shown by anglers averaging only 0.09 pink salmon per boat for the season. Anglers averaged 0.61 and 0.38 pink salmon per boat in 1968 and 1970, respectively. The total pink salmon harvest in 1971 was estimated at 746 fish. Pink salmon were most abundant in the fishery during early August.

Bear Lake Upstream Migration

Silver Salmon:

Despite an attempt to continuously detoxify (oxidize) Bear Lake's rotenone-treated outflows via four potassium permanganate (KMnO_4) drip stations, all fish ascending Bear Creek were probably killed. The factors related to this detoxification failure were: (1) insufficient quantity of KMnO_4 on hand to completely detoxify total Bear Lake outflows, (2) logistical problems (West Coast dock strike) in obtaining the second KMnO_4 shipment prior to the upstream migration period for Bear Lake silver salmon.

Fish kills (Dolly Varden) were reported in Salmon Creek downstream of the Bear Creek-Salmon Creek confluence three days after Bear Lake spillover occurred on August 8. No live adult silver salmon were observed in Salmon Creek above the Mayor Creek confluence, located approximately 2.5 miles downstream, until November 8 when five adults were observed spawning 100 yards below Bear Creek. At this time, caged juvenile silver salmon tested at the weir died in only 48 hours. By December 23, test fish died in 72 hours. Less than a month later (January 18), however, fish survived for approximately 30 days. Thus, Bear Lake surface waters (Bear Creek) remained toxic to salmonids nearly six months after lake treatment occurred.

The Bear Lake adult silver salmon migration was expected to be small in 1971. Bear Lake silver salmon smolts released past the weir in 1970 totaled 6,072 fish. An additional 6,400 hatchery-reared, Ad marked age 1.0 smolts (1968 brood, Bear Lake stock) were released below Bear Creek weir in 1970.

The marine survival of wild Bear Lake smolts released in 1969, which returned as adults to the weir in 1970, was 2.72%. If this marine survival were applied to the 6,072 Bear Lake smolts, an estimated 165 adults would have returned in 1971. An additional 93 adults (1.45% marine survival) were estimated to have returned from the 6,400 planted smolts, based on the 1970 Seward Lagoon-Bear Creek "jack" escapement ratio and the 1971 Seward Lagoon adult escapement. Therefore, the Bear Lake adult silver salmon escapement eliminated due to toxic outflows was estimated at 258 fish.

Other Species:

Most (87.6%) adult red salmon migrated upstream before Bear Creek was dewatered prior to lake rehabilitation. The first adult fish was captured in the upstream trap on June 20 and the last 50 red salmon were retrieved downstream on July 22 after stream dewatering occurred. A total of 403 fish were enumerated, with the highest daily count of 48 red salmon (11.9% of the run) occurring on July 11. The 353 fish sampled consisted of 184 males, 161 females, and 8 "jacks". The male-to-female sex ratio, excluding "jacks", was 1.1:1. A sample of 331 scales collected at Bear Creek weir disclosed the adult age composition to be 6.1% age 1.2, 21.2% age 2.2, and 70.3% age 1.3. Three age 1.1 (0.9%) and five age 2.1 (1.5%) "jacks" comprised 2.4% of the upstream migration. Mean fork lengths for ages 1.2, 2.2, and 1.3 fish were 484, 515, and 609 mm, respectively. Bear Creek water temperatures during the upstream migration ranged from 2.2° - 11.3°C (36° - 54°F) and stream flows, from 53 - 89 cfs.

The Resurrection Bay commercial fishery harvested an estimated 2,196 red salmon according to commercial fish tickets. The commercial fishing season was open continuously from May 17 until closed by emergency order on July 15. An estimated 15 red salmon spawned in the Grouse Lake system. Adjusting the total commercial harvest by the ratio of Grouse Lake to Bear Creek escapements (15:403), an estimated 2,117 (96.4%) red salmon harvested were of Bear Lake stock. Therefore, the estimated total Bear Lake run was 2,520 fish.

Adult Silver Salmon Timing and Abundance in Index Streams

Relative timing and abundance of adult silver salmon in the Resurrection Bay area have been measured each year since 1961 by foot surveys on selected index areas of seven clear streams near the road system. Timing of the 1971 escapements varied from mid-October to mid-November, and generally corresponded to periods of increased stream flows following rains. Peak of spawning occurred in one to two weeks after in-migration peaks. Minimum silver salmon escapements in each stream index area since 1967 are given in Table 7. The period from 1967 to 1971 encompasses one complete life cycle which is typically four years for Resurrection Bay silver salmon.

The total combined 1971 escapement declined somewhat compared to those for 1969 and 1970, and was the lowest observed since 1961. Escapements in the two lowest silver salmon producers, Airport and Mayor creeks, were only half those counted in 1970. The total combined escapement of 462 silver salmon may be conservative, however, because Grouse and Salmon creeks' escapements were necessarily estimated by their 1969-70 averages. Escapements bound for these tributaries were at least partially eliminated by toxic Bear Lake outflows entering Salmon Creek. Regarding the 1967 parent brood escapement of 1,122 adults, its dominant (age 2.1) cycle production was obviously low. Insufficient carcasses were examined on the stream surveys to present any valid sex ratios for these escapements.

TABLE 7 Minimum Silver Salmon Escapements in Seven Index Streams in the Resurrection Bay Area, 1967-1971.

Stream Name	Minimum Escapement					Mean 1967-70
	1967	1968	1969	1970	1971	
Airport	55	67	36	26	13	46
Clear	227	364	59	91	93	185
Dairy	99	98	115	66	46*	95
Grouse	174	378	168	131	150**	213
Jap	172	229	78	79	79	140
Mayor	66	41	64	38	19	52
Salmon	329	1,037	19	105	62**	372
Total	1,122	2,214	539	536	462	1,103

*Does not include 206 marked adults returning from hatchery-reared smolts released in 1970.

**Escapements were partially eliminated by toxic outflows from Bear Lake, and estimated by 1969-70 means to maintain continuity.

Silver Salmon Smolt Stocking Evaluation

Annual plants of marked, hatchery-reared smolts have been released in local waters since 1968. These smolt plants were discussed in detail by Logan (1969) and McHenry (1970; 1971). In 1968 and 1969, stocked smolts were of "exotic" sources (Big and Eagle creeks, Oregon, respectively), and showed insignificant survival to returning adults. Those few which did return, arrived in January and contributed little to the Resurrection Bay sport fishery which terminates in September. Therefore, smolts planted in 1970 and 1971 were of Bear Lake origin, in hopes that indigenous fish would realize better ocean survival and earlier inshore run timing to contribute substantially to the sport fishery.

A total of 39,750 Ad marked age 1.0 (1968 brood, Bear Lake stock) smolts were stocked in Seward Lagoon from May 19 to May 27, 1970. An estimated 66 marked "jacks", or 0.17% of the smolt plant, returned to Dairy Creek, a tributary of Seward Lagoon, during the 1970 fall spawning migration of natural Seward Lagoon silver salmon. A popular shore sport fishery resulted from these "jacks" as they schooled near the lagoon outlet culvert into Resurrection Bay. An additional 400 marked "jacks" were estimated caught in the shore fishery. An estimated 525 marked "jacks" and large smolts (immature males and females) were also taken by boat anglers during the 1970 Resurrection Bay sport fishery. Some of these fish, and possibly a portion of the "jacks" caught off the lagoon culvert mouth, probably resulted from 6,400 and 3,200 marked smolts planted in Bear and Box Canyon creeks, respectively, in 1970. The total 1970 marked smolt plant released in local waters was 49,350 smolts.

Marked adults surviving from the 1970 smolt plants contributed substantially to the 1971 sport fishery. Of an estimated 20,595 adult silver salmon taken during the census period (July 9-September 10) 4,527 fish were marked, or 22.0% of the season's harvest. Had the smolts not been stocked in 1970, the 1971 sport harvest would have been only slightly higher (16,068) than in 1969 and 1970, both relatively poor silver salmon years, averaging about 15,000 fish. As in 1970, an intense shore fishery developed when these marked fish schooled near the lagoon outlet culvert. This occurred from the peak of the sport fishery (silver salmon derby) to the end of September. An estimated 650 marked adults were taken in the shore fishery.

Despite the considerable sport harvests by boat and shore anglers, more than adequate spawning escapement returned to Seward Lagoon. An estimated 252 adults, comprised of 206 marked and 46 unmarked fish (Table 7), spawned in Dairy Creek and "Lagoon" Creek, a small spring-fed tributary to Seward Lagoon. After measuring the maximum spawning gravel available in these streams (1,280 yd²) it was determined that an estimated 91 spawning pairs (182 fish) could be accommodated in this area on the basis of 14 yd² required per spawning pair (Clay, 1961). When the observed magnitude of the initial escapement in Seward Lagoon was determined excessive of this number, Hatchery Services personnel artificially spawned 199 females for a source of hatchery silver salmon eggs. The total Seward Lagoon escapement, including the 252 fish which spawned naturally in the tributaries, 305 fish (including surplus males) artificially spawned, plus an estimated 50 fish that spawned in other areas of the lagoon, was 607 silver salmon. Since 87.3% of the naturally and artificially spawned fish were marked, an estimated 516 marked fish returned to Seward Lagoon. The marine survival of the 1970 smolt plant returning as adults to the lagoon, therefore, was 1.3% ($516/39,750 \times 100$).

The marine survival of the 3,200 marked smolts stocked in Box Canyon Creek in 1970 appeared to be in close agreement with that of Seward Lagoon. Of 14 silver salmon carcasses checked in Box Canyon Creek, 7 were marked. This confirmed observations that many adults spawning were marked but could not be physically examined as carcasses. A total of 57 marked adults were estimated in the Box Canyon Creek escapement, providing a marine survival of planted smolts to returning adults of 1.8% ($57/3,200 \times 100$).

Marked smolt plants utilizing Alaskan origin silver salmon are being continued in Resurrection Bay tributaries so long as they provide similar contributions to the marine sport fishery as that observed in 1971.

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